Technical University of Denmark

Revised cost estimate for the decommissioning of the reactor DR3

Iversen, Klaus

Publication date:
2001

Document Version
Publisher's PDF, also known as Version of record

Citation (APA):
Iversen, K. (Ed.) (2001). Revised cost estimate for the decommissioning of the reactor DR3. (Denmark. Forskningscenter Risoe. Risoe-R; No. 1291(EN)).

Risø-R-1291(EN)

Revised Cost Estimate for the Decommissioning of the Reactor DR 3

Edited by Klaus Iversen

Risø National Laboratory, Roskilde
November 2001

Abstract The report describes a revision of the cost estimate for the decommissioning of the research Reactor DR 3 as described in the report Risø-R-1250(EN) “Decommissioning of the Nuclear Facilities at Risø National Laboratory” Edited by Kurt Lauridsen.

The revision has been performed by the planning group in the Risø Decommissioning Department, and has been carried out as a discussion and evaluation of procedures methods and necessary resources to overcome the different phases of the the decommissioning task of the Reactor.

ISBN 87-550-2935-3; 87-550-2936-1 (Internet)
ISSN 0106-2840

Print: Pitney Bowes Management Services Denmark A/S, 2001

Contents

1 Introduction

This report comprises a revision of the cost assessment of the decommissioning of Reactor DR3 as it has been described in Appendix 3 in the report Risø-R-1250(EN) "Decommissioning of the Nuclear Facilities at Risø National Laboratory - Descriptions and Cost Assessment" Edited by Kurt Lauridsen Risø National Laboratory, February 2001 (ref. 1).

The revision has been carried out by the planning group in the Risø Decommissioning Department, and deals only with the 20 years scenario.

It is not considered to be meaningful to go into a revision of the more distant activities in the 35 years and 50 years scenarios described in the above mentioned report, as these scenarios may comprise to day unknown preconditions and techniques.

The revision has been performed as a discussion in the planning group of possible methods and necessary resources to overcome the different phases of decommissioning work on the technical installations of the reactor.

Following good international practice and recommendations from IAEA (International Atomic Energy Agency), a decommissioning project is carried out at three levels: Initial, Ongoing and Final. For a given nuclear installation, the degree of detail will increase from the initial to the final decommissioning plan.

This report must be considered as belonging to the initial planning (level 1).

It is planned to follow this initial planning with a more detailed project when the preconditions for the decommissioning are known to a higher extent.

It is evident that a great deal of uncertainty related to the cost estimates exists at this early stage of planning. These uncertainties originate from the fact that the formal preconditions for the decommissioning work do not exist at the moment. It has been assumed that the current legislative, health and safety and other criteria (e.g. radiation dose limits) will be appropriate. This of course gives rise to uncertainties if possible future changes inside these areas are realised. The specific uncertainties are described under each chapter in the report.

Another contributor to the uncertainty is the fact that the placing and the projecting of the final repository are not decided at the moment. This of course brings uncertainty in relation to the transportation cost.

Programme manager Mr. Roy Manning from UKAEA (United Kingdom Atomic Energy Authorities) reviewed this report and gave most valuable comments during a seminar held at Risø National Laboratory on 29 October 2001. The comments are attached in Appendix 1.

2 General description of Reactor DR 3

This section is an unchanged reprint of the corresponding section in ref. 1 pp. 27-34.

DR 3 was acquired for the Danish Atomic Energy Commission (AEK) in accordance with a contract between AEK and the English company Head Wrightson Processes (HWP).

The buildings and technical installations were designed by Steensen & Varming working together with Professor Preben Hansen and Mogens Balslev, partly on the basis of the English projects for corresponding work on Pluto.

Danish reactor no. 3, DR 3 in short, is a research reactor built to test materials and new components for power reactors. It has been designed in accordance with drawings used during the construction of the two English reactors Pluto at Harwell and DMTR at Dounreay.

The reactor uses 19.75% enriched uranium in the fuel elements, and is moderated and cooled using heavy water. The reactor core consists of 26 fuel elements, which together contains approx. 3.3 kg of U-235, on average during routine operation at 10 MW. These elements are arranged in a square grid on the bottom of a D_2O-filled aluminium tank. Around the core, part of the heavy water acts as a reflector, and outside the aluminium tank, on the sides and under the bottom of this, is a graphite reflector approx. 30 cm thick. All this is contained in a steel tank, the walls of which are clad with boral and lead, to reduce the thermal neutron and gam-ma radiation from the core. On the outside is a biological shield of barytes concrete.

A total of 18 experimental tubes are located around the reactor core. Four of these are horizontal tangential tubes with a diameter of 7". The remaining 14 facilities are all vertical tubes, of which 4 x 7" tubes and 4 x 4" tubes are immersed in the heavy water in the aluminium tank, while the remaining 6 tubes are 4" tubes in the graphite reflector. It is also possible to place experimental materials in the 2" tubes located in the middle of the fuel elements.
At 10 MW, the maximum thermal and fast flux is approx. 1.5×10^{14} n/cm^{2}s and approx. 4.5×10^{13} n/cm^{2}s respectively.

Position of buildings
The reactor complex, shown in Figure 1, is located in the western part of the Risø peninsula on a filled-in area north of the central road. Around the central reactor hall, building 213, are a number of buildings housing the necessary auxiliary machinery for the reactor. In a long wing running south-north in building 214 immediately to the east of the reactor hall, there is a “red” store furthest south, i.e. a store for low level radioactive equipment. Following this is a hall, the AH hall (Active Handling) with storage facilities for spent fuel elements and irradiated material, together with workshop areas for the maintenance of radioactive equipment. On the south wall of the hall is a distillation plant for processing degraded heavy water. After this comes a workshop hall (machine shop), and to the north of this are a number of offices intended for operating personnel, along with several changing rooms connected directly to the staff entry lock to the reactor hall.

Lying due north of the reactor hall is building 215, the so-called operations building, which houses the air-conditioning and cooling systems for experiments, compressed air plants, transformers, the main electrical distribution panel and a diesel plant for the stand-by power supply. Two emergency power batteries and electrical inverters are each located in their fire section in a side wing to the storage building north of building 215. To the west of the reactor hall and running south-north is building 217 (pump house), which as well as housing the secondary main and shut-down pumps accommodates part of the ventilation equipment and a water treatment plant. This plant is to provide the reactor with make-up water for the secondary cooling circuits and supply demineralized water to the entire Risø area. Lying due south of the reactor hall, at a distance of approx. 50 m from it, is building 218, which houses an emergency control room with remote indicating instruments for a number of parameters.

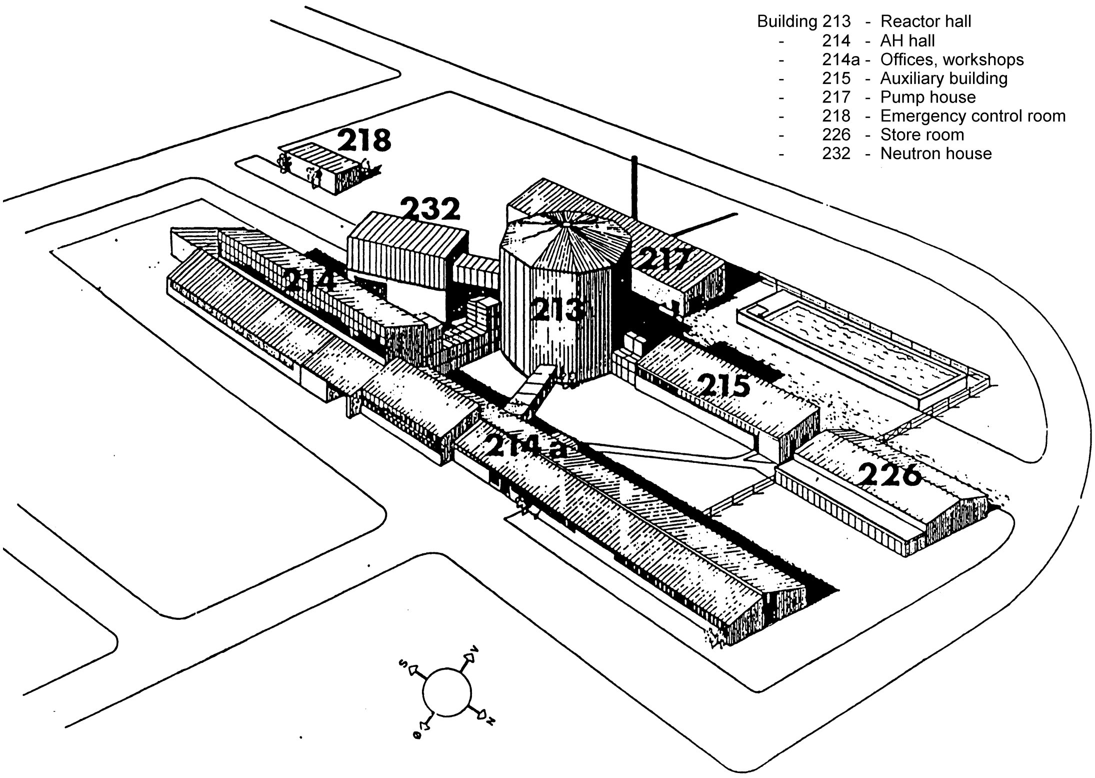


Figure 1 The DR 3 complex

Reactor hall

The reactor itself appears as a square, ironclad concrete block with sides measuring 6.1 m in length and a height of 10.53 m, see Figure 2 and Figure 3. The four facades are to all intents and purposes oriented to the points of the compass, and are numbered so that façades 1, 2, 3 and 4 face north, east, south and west respectively.

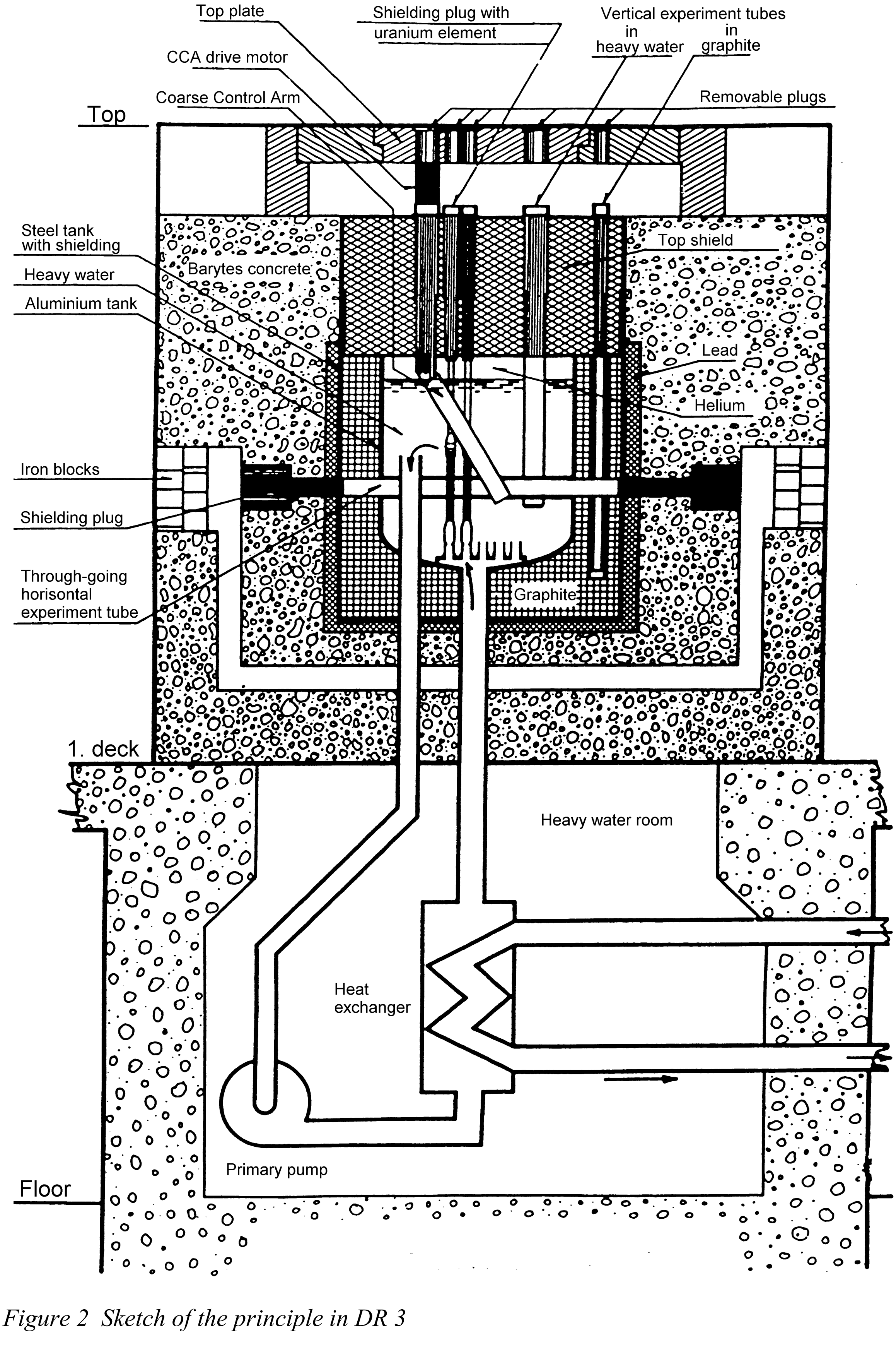


Figure 2 Sketch of the principle in DR 3

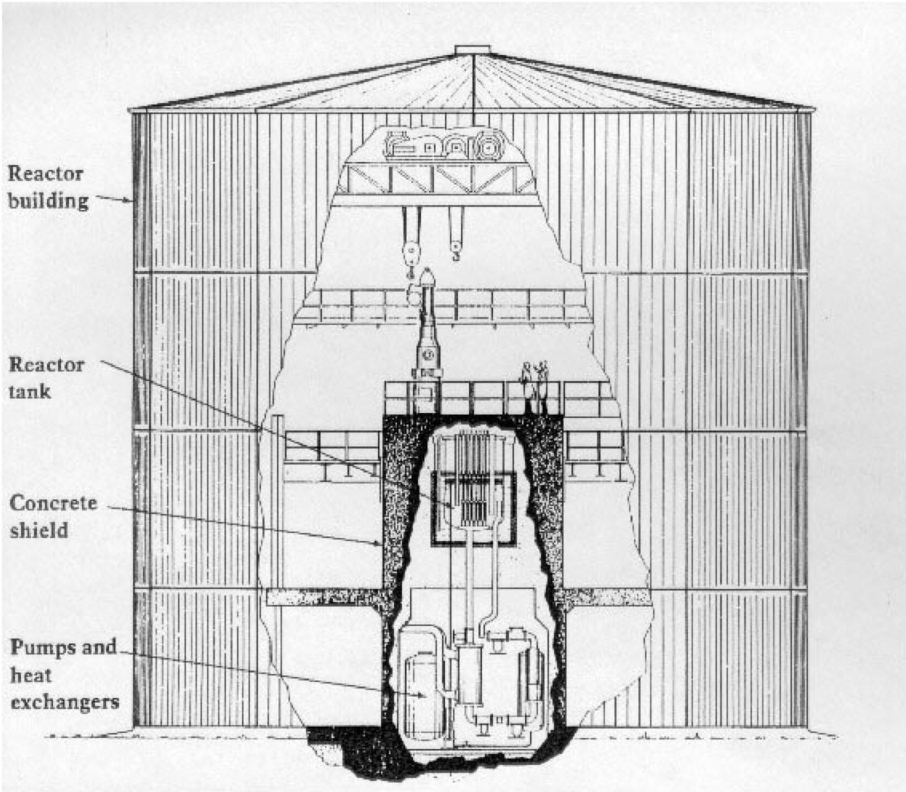


Figure 3 "X-ray picture" of the reactor building, showing size and position of the reactor.

The reactor block is positioned centrally in a hall created by an airtight cylinder with an internal diameter of 21 m and an internal height of 22.4 m at the centre. This produces a total volume of approx. 8000 m^3. The structural elements are positioned externally together with the insulation, so that seen from the outside the hall is 10-sided and clad with profiled aluminium sheets.

The hall is served by a ring crane with a lifting capacity of 25/10 tonnes. Its free lifting height above the reactor top is about 7 m.

The hall is divided into three levels: the basement, 1st level and reactor top with movable floor. These are connected on the one hand by stairs and on the other by a combined passenger and goods lift with a capacity of 550 kg.

The hall is entered via a staff entry lock and a vehicle entry lock. There is also an emergency entry lock on the 1st level, which is a marked escape route for persons coming from the reactor top and 1st level.

Reactor basement

The staff entry lock opens into the reactor basement opposite façade 2, as shown in Figure 4. Sited along this facade is the control room, from where operation of the reactor is controlled and monitored. The room measures 15 m^2 and has exits to both north and south. It houses most of the reactor's control -equipment, including a centrally located control desk with automatic and manual control of the reactor's control elements.

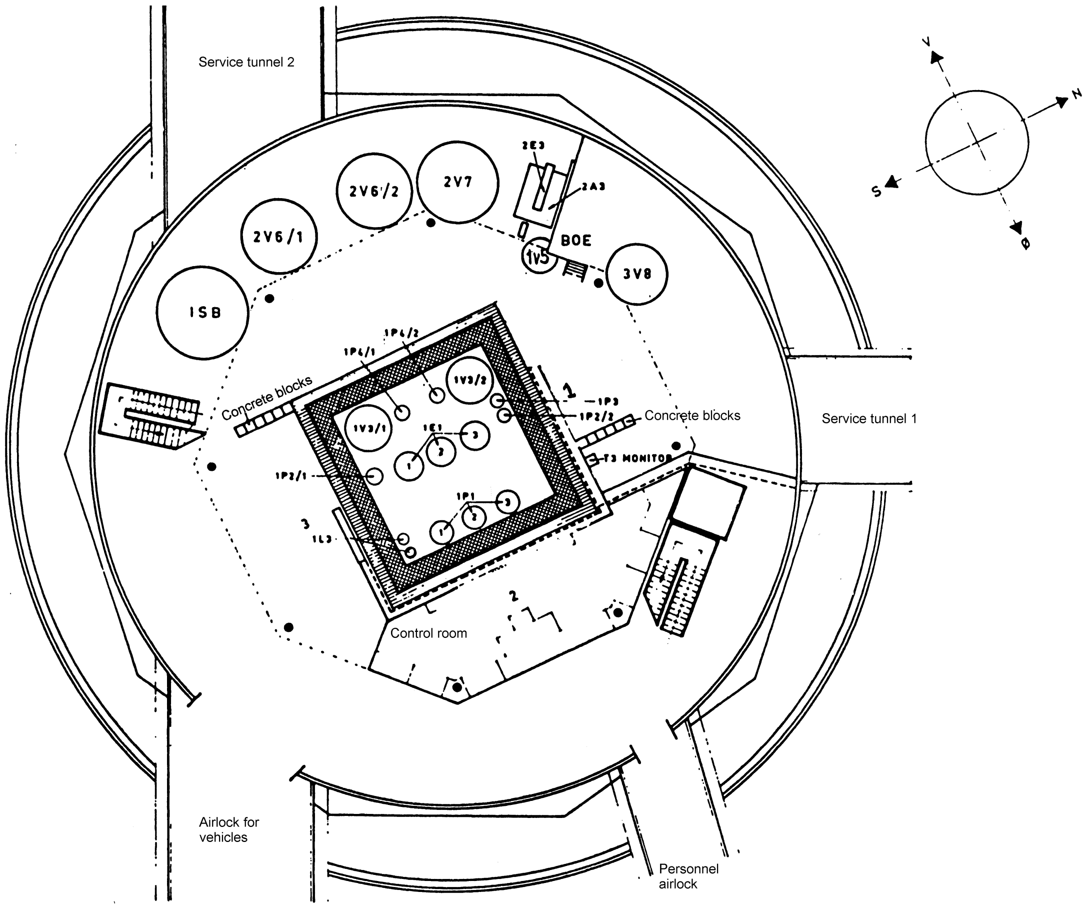


Figure 4 Horizontal cross section, basement level

Apart from the opening to the staff entry lock, the hall wall outside façade 2 is covered by electrical terminal boards (panel 5).

Outside facade 3 there is an open area connecting to the vehicle entry lock. This is used for transportation into and out of the hall, and for crane traffic between the three levels, the floor above having an opening roughly 40 m^2 in size. Part of this opening is blocked up at present by a gangway holding a neutron guide tube. From facades 3 and 4 there is access to a room (D_2O room) in the reactor block. The dimensions of this room are 5 x 5 m^2 and its height is 5.5 m, as the floor is 94 cm lower than the basement floor. The room contains pumps, heat exchangers and various tanks for the primary circuit. Access to this room is blocked during normal operation, and the high-density concrete walls of the reactor block shield the remaining part of the radiation coming from the primary water during operation.

A concrete cylinder ISB (Internal Storage Block) is located against the hall wall at the corner between facades 3 and 4. It houses irradiated fuel elements and experiments.

Opposite facade 4 are two expansion tanks and a gas tank for the helium used as cover gas above all heavy water surfaces. A heat exchanger for the shield cooling system is located between the gas tank and the hall wall. There is a purging and drying system for helium outside the corner between facades 4 and 1, and on a platform above, a helium cooler along with measuring instruments and recombiners for the D_2 and O_2 content of the helium system. In addition, there is a vessel here that is used for draining and transfers of D_2O (1V5).

All branch connections for the shield cooling system exit under the ceiling at facade 1, close to the corner with facade 4. The helium circulators are situated opposite and adjacent to these is a gas tank for CO_2 gas for the graphite reflector, behind which are the pumps for the shield cooling system. The hall wall opposite facade 1 is taken up by electrical panels (panel 4) supplying most of the motors in the reactor cooling systems and by an alarm panel for shield cooling and gas.

The lift is located outside the corner between facades 1 and 2 and adjacent to this are stairs leading up to the 1st level and the reactor top.

Building 214/214a

Normal access to the DR3 plant is through the entrance hall of the office wing. An electronic system ensures that only those with permission to enter can do so unaccompanied.

From the entrance hall, access is provided via the central aisle on the one hand to various offices etc., and on the other to the staff entry lock of the reactor hall and the workshop areas. The area in front of the staff entry lock and the workshops at the southern end of the building is a blue classified zone, in which personnel must wear overalls.

Adjoining the entrance area to the reactor hall, in addition to the washbasins and radiation monitors for checking staff, there are also showers for decontaminating personnel. Entry to the decontamination showers is exclusively via the health physics laboratory, immediately adjacent to the staff entry lock. These showers and washbasins by the lock entrance are connected to the active drainage system, whereas the bathing area in the white zone is connected to the normal drainage system.

AH hall

The AH (Active Handling) hall measures 12 x 39 m^2. It is served over its entire length by a travelling crane, the double lift of which has a capacity of 25/5 tonnes and a maximum lifting height of 7.6 m. The entrance to the hall from the changing room is at the north gable. At the northern end, to the west, is the entrance to the vehicle lock and access to the open air, while to the east there is a portal opening onto the outside. In the southern gable there is a so-called "red" store for active objects. A red classified zone has been established in the western and southern part of the hall (higher permitted contamination/ radiation level than in the blue zone), and along the wall there are a number of service stations with compressed air, water, drainage, electricity and a connection to a ventilation system with a separate exhaust. In the floor of the zone, close to the entrance to the vehicle lock, is a storage facility (EFESB = External Fuel Element Storage Block) with 80 positions, intended for the storage of spent fuel elements which no longer have to be cooled. A pit (VEFSB = Vertical Experimental Facilities Storage Block) located to the east of this has 24 storage spaces (229 mm Ø tubes) for irradiated experiments from the vertical experimental facilities. Both these pits are ventilated. Another pit, 1.83 x 1.83 m^2 and 1.07 m deep, is situated south of the EFESB. This is used for storing irradiated fuel element plugs and other radioactive equipment. South of this pit, a shielded facility has been erected for the connection of new fuel elements with reused shielding plugs. In the hall floor south of the VEFSB there are two apertures of 250 mm Ø and 3.55 m deep, which are used in connection with operations in the Boucher cell. Further south is an area intended for the inspection of the heavy water pumps, although part of this work is carried out in a special decontamination room. To the south of this is an area for inspection and maintenance of the control equipment. The area contains a lead-shielded cell, test stand and workroom. Further south is an area used for parking the horizontal flask 9R10 and the fuel tube flask 9R4.

Four blocks in the floor each containing 12 holes are for the intermediate storage of released fuel tubes. At the southernmost end of the AH hall is a fourth zone around the cutting basin for fuel elements. The basin is 4 x 5 m^2 and 4.5 m deep and is the place where the fissile zone is cut free from the rest of the fuel elements. The fissile zones (tubes) are stored in racks. The basin has a separate cleaning circuit with filter and ion exchanger located in a pit to the west of the basin.

A distillation column for upgrading of heavy water quality has been set up along the south wall.

The handling equipment for the cutting basin is suspended on the southern part of the east wall, and on the south wall itself is a system for filling and emptying the heavy water ion exchangers. Further north, by the east wall, is a pump stand for the heavy water pumps and an evaporation plant for heavy water rags. There is an annex of 3.7 x 7.5 m^2, height 3.5 m, in the northern part of the east wall. The annex consists of concrete walls around 30 horizontal 245 mm Ø steel tubes, intended to hold irradiated experiments and plugs from the horizontal experimental facilities. Situated behind this storage block is a smaller room, which is used for cleaning slightly contaminated tools and equipment. A further (large) decontamination room is located adjacent to this and is laid out as a wet room, where larger items can be handled and decontaminated. This room is used, for example, when working on the heavy water pumps.

The premises of the isotope department, where silicon irradiation is handled, can also be accessed from the AH hall.

Machine shop
The entrance to the workshop is located in the north gable of the AH hall. The workshop hall is 9 x 18 m^2 and is served by a lifting crane with a max. capacity of 1t and a lifting height of 4m. The workshop has supply lines for compressed air and electricity. A portal in the south wall offers access to outside; the passage is intended for the transportation of large objects to and from the workshop and is normally closed off. The workshop is located in the classified zone, so that work can be undertaken on contaminated/active equipment.

Auxiliary building, Building 215
In the auxiliary building running north-south and situated north of the reactor hall, there is a machine hall measuring 28 x 9 m^2 and below it a basement of a similar floor area. The northernmost end of the building contains two transformer rooms, one of which houses a 1600 KVA transformer for operating the reactor. The other transformer room holds a transformer for operating Risø's heat pump plant. The north wall of the hall is taken up by the main electrical distribution panel.

The northern part of the building is taken up by 2 diesel generators for the stand-by supply (DG1, 120 KVA and DG2, 250 KVA). In the centre of the building is an air compressor, which acts as a stand-by for the compressed air supply from the boiler house. Located in the southern part of the building is the air inlet system for the reactor hall's ventilation plant, and cooling machinery for the air conditioning system (and for experiment cooling).

The central part of the basement accommodates tanks and distribution system for compressed air. The southern part constitutes a separate room, which contains pumps, valves and an electrical panel for experiment cooling. The room also contains the pump arrangement for emptying the lift sump (following use of the sprinkler system in the hall), and the GAKO valve for closing off the hall's air inlet connection in the event of a major release of activity in the hall.

Pump house, Building 217
The pump house, running north-south and situated west of the reactor hall, is divided up into three rooms. In the northernmost of these, measuring 9 x 15 m^2, are the two main pumps and the two shut-down cooling pumps, which circulate the secondary cooling water between the heat exchangers under the reactor and the fjord cooling plant. The main pipes and branches with shut-off valves for the pumps are located in a pit along the western side of the room.

The basement contains two 10 m^3 tanks for non-active discharges and adjacent to these is a tank pit for 2 x 10 m^3 tanks for active discharge.

The centre room, measuring 9 x 12 m^2, houses extractor fans and filters for the ventilation system and in the basement room beneath this are 3 GAKO valves with related water tanks. One is situated in the outlet from the ventilation system to the absolute filters and extractor fans to a 22 m high chimney situated immediately to the west of the building. The other two are located in a recirculation branch with filter and fans for the ISB. There are also two shut-off valves for the active ventilation system in service tunnel II. The two 5 m high air traps for wastewater from the reactor hall are also to be found here. The air discharged from the system is monitored before being discharged via the chimney. The monitor effecting an isolation of the hall from the surroundings (building seal) if a certain level of activity is exceeded. The overall activity at the main filters and the active ventilation filters is also monitored.

The southernmost room houses the water treatment plant for the production of demineralized water for Risø. This only occupies a small part of the room, with the rest being used for storage purposes.

Storeroom, Building 226
To the north of the operations building is a building running north-south, which holds spares for the various reactor systems and consumer stores.

Battery room
Along the eastern side of the storeroom is a building containing the batteries for the guaranteed supply, the direct current inverters, which supply emergency power to the primary shut-down pumps and the emergency cooling pumps.

Emergency control room, Building 218
Situated to the south of the reactor hall is the so-called emergency control room, which is constructed as a shelter, with walls 90-125 cm thick and a concrete ceiling 100 cm thick. The room, which measures 4.3 x 7.8 m^2 and is 2.4 m high, contains an emergency control console, from which certain functions in the reactor hall can be controlled remotely and monitored.

The room is ventilated via absolute filters to guarantee clean air even if the outside air is contaminated following an accident.

Neutron house, Building 232
Through a guide tube cold neutrons were led to spectrometers placed in the neutron house, south of the reactor building. In addition to the experimental facilities, there are offices and workshops in the neutron house.

3 Decommissioning of Reactor DR 3

Preconditions

The following preconditions are valid in general.

It is assumed that a 20 years scenario for the decommissioning of the nuclear installations will be chosen.

The geographical placing of the final repository is not chosen for the moment. This of course influences the transportation cost for the radioactive waste.

It has been assumed that current legislative, health and safety and other criteria (e.g. radiation dose limits) will be appropriate. This of course causes the risk that unforeseen possible future changes may render some procedures inappropriate.

The calculated radioactive inventories and dose rate are based on the best information at hand to date. Future measurements may change the actual values which in turn may cause changes in dismantling and packing procedures.

It is assumed that overall 25% of external assistance will be used thereby giving a salary payment rate of 350 DKK per hour.

It should be noted that costs concerning management and health physics activities are not included. These costs are included in ref. 1.

Cost Items

Based on:
NEA/IAEA/EC “A proposed standardised list of items for costing purposes in the decommissioning of nuclear installations - Interim Technical Document", 1999.

01 PRE-DECOMMISSIONING ACTIONS

Cost for pre-decommissioning actions have not been treated in this report.

02 FACILITY SHUTDOWN ACTIVITIES (Cost: 7 MDKK)

Section 02 covers all activities relating to shutdown operations of the facility.
It has 13 groups:

02.0100	Plant shutdown and inspection
02.0200	Removal of fuel and/or nuclear-fuel materials
02.0300	Drainage and drying or blow down of all systems not in operation
02.0400	Sampling for radiological inventory characterisation after plant shutdown, defuelling and drainage and drying or blow down of systems
02.0500	Removal of system fluids (water, oils, etc.)
02.0600	Removal of special system fluids (D_2O, sodium, etc.)
02.0700	Decontamination of systems for dose reduction
02.0800	Removal of waste from decontamination
02.0900	Removal of combustible material
02.01000	Removal of spent resins

02.01100 Removal of other waste from facility operations
02.01200 Isolation of power equipment
02.01300 Asset recovery: Resale/transfer of facility equipment and components as well as surplus inventory to other licensed (contaminated) and unlicensed (non-contaminated) facilities

02.0100 Plant shutdown and inspection.

02.0101 Termination of operation, plant stabilisation, isolation and inspection.
At the end of the last operation period, the reactor has been brought to a normal shutdown in accordance with normal shutdown procedures.
The site-staff was at that time still at the normal operational level in number and capacity.
After shutdown, the operations staff should make and document a survey of all systems necessary for the coming prolonged cooling period. The mentioned 300 man-weeks include the time from reactor shutdown.

Cost: 300 man-weeks.

During the "cooling period" the operational staff performed continuous surveillance of the plant. All parameters indicating radiation levels, contamination, cooling flows, temperatures etc. were monitored and surveyed.

Some of the operations covered under this section are already going on to a certain extent as far as the ruling conditions for operating permits, while others are not even planned at the moment. Of course the demand for resources for the unplanned operations are uncertain at this stage of the process. The operational limits and conditions for the closed down reactor are currently revised and approved by the Danish Authorities. Inspection and surveillance are continued in a well-defined scope, which reduce the uncertainty of the cost estimate for this activity.

02.0102 Facility reuse.
Identification, isolation and conservation of systems to be reused should be performed.
Essential systems like power-supply, water and ventilation can be useful in later stages of the decommissioning period.
Roads, plantings, buildings and other infrastructure elements should be evaluated for later uses.

Cost: 10 man-weeks.

The removal of fuel from the reactor core has been finished. Half of the fuel elements have been shipped abroad. This operation is planned in details and is not expected to give substantial uncertainty to the estimate.

02.0200 Removal of fuel and/or nuclear-fuel materials.

02.0201 Defuelling and transfer of fuel to temporary spent-fuel storage.
All the fuel-elements from the reactor core have been transferred to the external storage block (outside the reactor hall).
After a cooling period in the external storage block, the spent fuel-elements should be transferred to the fuel-element cutting-pool, where the uranium containing parts of the elements are cut out, and transferred to the intermediate storage block.

Cost: 70 man-weeks.

02.0202 Nuclear-fuel material inventory recovery.
The spent fuelelements are sent abroad. No special expenditures are foreseen in connection with the nuclear fuel material.

02.0300 Drainage and drying or blow down of all systems not in operation.

Drainage, blow down and drying of systems no longer in use should be carried out by the operations staff.
Cost: 4 men 4 weeks = 16 man-weeks.
Drainage and drying or blow down of all systems not in operation and removal of system fluids has partly been carried out or planned in details. These activities are not expected to give considerable uncertainty to the estimate.

02.0400 Sampling for radiological inventory characterisation after plant shut down, defuelling and drainage and drying or blow down of systems.

02.0401 Sampling for radiological inventory characterisation in the installations after plant shutdown, defuelling and drainage and drying or blow down of systems.

02.0402 Subgrade soil sampling and monitoring wells to map contamination plumes.
Cost: Included in health physics-cost, cf. ref. 1 section 6.9 and Appendix 5.

02.0500 Removal of system fluids (water, oils, etc.).

This headline includes removal of all non-active fluids.
The largest volume (about 90 m^3) is present in the secondary cooling system (system 04).
The system contains inhibited freshwater that should be drained to the sewage system.
Apart from the above-mentioned, only small amounts of lubricating oils from pumps etc. are present (about 200 l).

Cost: 1 man-week.

02.0600 Removal of special system fluids (D_2O etc.).

The heavy water from the primary circuit (about 10 m^3) should be drained and filled on stainless steel drums for storage.
The water contains Tritium. Further about 5 m^3 of tritiated heavy water for supply purposes are stored in stainless steel drums at the plant.
Cost includes upgrading of the D_2O volume.

Cost: 50 man-weeks.

Removal of D_2O from primary circuit includes drying of system and upgrading of the heavy water, which are long-ranged operations with low working intensity. In addition the drying method is not determined yet. The estimate of these activities is rather uncertain.

02.0700 Decontamination of systems for dose reduction.

The primary D_2O-system may be slightly contaminated, and therefore some action with regard to decontamination may be beneficial.

Cost: 12 man-weeks.

The estimate for decontamination of systems for dose reduction is rather uncertain, as the manpower needed is of resources not known at present.

02.0800 Removal of waste from decontamination.

Considered as an ongoing process during the decommissioning period. The cost is contained under the specific item.

02.0900 Removal of combustible material.

Task that comprises following:
- Small amounts of lubricating oil and diesel fuel.

- Removal of cables and electrical cabinets.

Cost: 110 man-weeks.

02.1000 Removal of spent resins.

Task comprising transfer of about 50 l of spent resin from the primary circuit ion-exchanger

02.1100 Removal of other waste from facility operations.

Task including small amounts of contaminated water, unused resins, paper etc.

Cost: 5 man-weeks.

02.1300 Asset recovery: Resale/transfer of facility equipment and components as well as surplus inventory to other licensed (contaminated) and unlicensed (non-contaminated) facilities.

Relevant spare parts will be sold if possible to the operating sister reactors of DR 3.
No net income is calculated under this point.
The asset recovery is estimated to balance with no net income. However the amount of components in question is little.

03 PROCUREMENT OF GENERAL EQUIPMENT AND MATERIAL (Cost: 9 MDKK)

Section 3 covers all activities relating to the purchasing of general equipment and materials at site level. It comprises 4 groups:

03.0100 General site-dismantling equipment
03.0200 Equipment for personnel/tooling decontamination
03.0300 Radiation protection and health physics equipment
03.0400 Security and maintenance equipment for long-term storage

The investments treated below covers those demands that can be identified at this early stage where the planning of the decommissioning has not been performed to any detail. This of course adds to the uncertainty of the amounts mentioned.
Before better accuracy of the investments can be obtained the work-tasks and methods have to be planned, thus giving a base for making calculations about the necessary equipment and material.

Procurement of special-purpose or other specific equipment is included in the respective cost groups/items.

03.0100 General site dismantling equipment.

Investment and maintenance for general site-dismantling equipment, including installation, testing, licensing (operational activities to be included in decommissioning activities however), essentially comprising lifting gear, such as:

-Overhead cranes, trucks etc. Cost: 5 MDKK
-Hiring of special lifting gear. Cost: 3 MDKK

03.0200 General equipment for personnel/tooling decontamination.

Investment for and maintenance and subsequent dismantling of additional equipment for personnel and/or tooling decontamination, including installation, testing and licensing (operational activities included in decommissioning activities, however).

Cost: 1 MDKK

03.0300 General radiation protection and health physics equipment.

Included in Applied Health Physics, cf. ref. 1 section 6.9 and Appendix 5.

03.0400 General security and maintenance equipment for long-term storage.

Equipment required for the surveillance of facilities either pending decommissioning or being partially dismantled, in view of minimising personnel Cost during long-term storage, including installation, testing, licensing (operational activities are included in decommissioning activities, however). (Not relevant in 20 years scenario)

04 DISMANTLING ACTIVITIES (Cost: 249 MDKK)

Section 4 covers all activities relating to the different actual dismantling operations. Depending on the selected option, dismantling activities and related cost items in view of a dormancy period or in view of other "standard" or specific decommissioning stages can be applicable.
It should be born in mind that all the mentioned dismantling activities have not been projected or planned in any detail at this early stage of decommissioning. This of course influences the uncertainty of the cost figures.
The planning of all the activities will be carried out during the coming years.

The section is divided into 24 groups:

04.0100	Decontamination of areas and equipment in all buildings to facilitate dismantling
04.0200	Drainage of spent-fuel pool and decontamination of linings
04.0300	Preparation for dormancy
04.0400	Dismantling and transfer of contaminated equipment and material to containment structure for long-term storage
04.0500	Sampling for radiological inventory characterisation in the installations after zoning
04.0600	Site reconfiguration, isolating and securing structures
04.0700	Facility (controlled area) hardening, isolation or entombment
04.0800	Radiological inventory categorisation for decommissioning and decontamination
04.0900	Preparation of temporary waste storage area
04.01000	Removal of fuel-handling equipment
04.01100	Design, procurement, and testing of special tooling/equipment for remote dismantling
04.01200	Dismantling operations on reactor vessel and internals
04.01300	Removal of primary and auxiliary systems
04.01400	Removal of biological/thermal shield
04.01500	Removal of other material and equipment from containment structure and all other facilities, or removal of entire contaminated facilities
04.01600	Removal and disposal of asbestos
04.01700	Removal of pool linings
04.01800	Building decontamination
04.01900	Environmental cleanup
04.02000	Final radioactivity survey
04.02100	Radioactive material characterisation
04.02200	Decontamination for recycling and reuse
04.02300	Personnel training
04.02400	Asset recovery: Sale/transfer of metal or materials, and salvaged equipment or components for recycle or reuse

The activities described in this section is very much dependent on the coming legislative and other formal frames that have to be set up by the Danish Authorities.
As the framework for the activities is not known at present a great deal of economic uncertainty is connected to the presented costs.
The specific methods of decommissioning are not projected and known at the moment. This also contributes to the economic uncertainty.

04.0100 Decontamination of areas and equipment in buildings to facilitate dismantling.

Decontamination of areas and equipment in all buildings to be placed into dormancy outside the containment building.
Outside the containment only minor tasks are considered necessary in order to decontaminate, as all these areas during operation continuously were kept in a decontaminated state. Only a throughout survey and monitoring for radioactivity should be carried out.
Cost: Included in Applied Health Physics, cf. ref. 1 section 6.9 and Appendix 5.

04.0200 Drainage of spent-fuel Cutting-pool and decontamination of linings.

Drainage should be done to the active water effluent system for further processing at the radioactive waste treatment plant.
Erection of plastic tent above spent-fuel pool to contain loosened contamination in the following high pressure rinsing sequence.

Cost: 10 man-weeks.

Decontamination of the stainless steel surfaces of the spent-fuel pool (high pressure-rinsing/ washing).

Cost: 20 man-weeks.

04.0300 Preparation for dormancy. (10 years)

04.0301 Zoning for long-term storage. (10 years)
Layout of dormancy control area is considered to encompass the following buildings in the DR3 complex: containment- building, the active handling bay and the office building.
To minimise the radiological controlled area requiring service and maintenance the former service building's ventilation, electrical power supply, and secondary system pump house should be decommissioned.

Decommissioning of the above mentioned buildings and systems.

Cost: 2.5 MDKK

(ref. to report from DEMEX Rådgivende Ingeniører A/S)

Reorganisation, cleaning and decontamination operations in rooms, areas and equipment in order to release buildings not to be used in subsequent decommissioning period (phase 3).
As the demand for decontamination has not been identified at present a great deal of uncertainty is related to this figure.

Cost: 1,0 MDKK

Redesignation, and re-engineering of materials and equipment for minimum configuration, including:

- -Redefinition of secured area.
- -Modification or reconstruction of security.
- -Surveillance and monitoring equipment.

Cost under this point not relevant in the 20 year decommissioning scenario.
Deenergising and isolation of non-essential systems.

Cost: 1 MDKK

Replacement of equipment and systems used during operations, with more efficient or less complex services, such as:
- -Ventilation
- -Lightning
- -Access control, etc.

Cost under this point not relevant in the 20-year decommissioning scenario.

04.0302 Removal/ disposition of inventory not suitable for long–term storage.
About 15 tons of tritiated heavy water should be sought sold. Perhaps to operating heavy-water moderated power reactors.
Cost: no net income/expenditure is calculated.

The stock of irradiated experimental facilities rigs, liners, spectrometers should, after suitable size reduction be loaded into storage casks and transferred to medium active repository.
The possible procedure and necessary process and equipment are not projected at the moment, which of course influences the cost estimate.

Cost: 8 MDKK

04.0400 Dismantling and transfer of contaminated equipment and material to contain ment structure for long-term storage.

It is not planned to bring any considerable amounts of contaminated equipment into the containment-building. Peripheral equipment and structures should be decontaminated as far as possible followed by release to non-radioactive scrap.

04.0500 Sampling for radiological inventory characterisation in the installations after zoning and in view of dormancy.

Cost: Included in Applied Health Physics, cf. ref. 1 6.9 and Appendix 5.

04.0600 Site reconfiguration, isolating and securing structures.

Site reconfiguration, isolating and securing structures are relevant activities only in the 35- and 50 years scenarios.

04.0700 Facility (controlled area) hardening, isolation or entombment.

These activities are only relevant in the 35- and 50 year scenario.

04.0800 Radiological inventory characterisation for decommissioning and decontamination.

Cost: Included in Applied Health Physics, cf. ref. 1 section 6.9 and Appendix 5.

04.0900 Preparation of temporary waste storage area.

It is foreseen that a temporary waste storage of 400 m^2 (80 % from DR3) is needed. A covered building for such a purpose should be erected.

Cost: 15 MDKK

04.1000 Removal of fuel-handling equipment.

Removal and extraction of fuel handling equipment and associated components from a temporary storage area, pool, storage blocks, viewing-boxes etc.
Not including decontamination (for that see 04.2200).

Cost: 100 man-weeks.

04.1100 Design, procurement, and testing of special tooling/equipment for remote Dismantling.

The considerations and planning under this item are by any means the most intricate and difficult, and has not been carried out in any detail at the moment leading to a great uncertainty of the estimated cost.

04.1101 Design and procurement of special tools for dismantling the reactor vessel and internals
Considerations about dismantling alternatives for the reactor vessel and internals by cutting or by removal and disposal of the vessel and internals as a single package for which design and procurement of special tooling would be associated with the preparation, rigging and lifting of the package as well as shielding, weather enclosure, cradles etc., needed to transport the vessel and internals.

Cost: 200 man-weeks.

Considerations about working environment an constraints such as handling requirements, packaging requirements, transportation requirements etc.

Cost: 80 man-weeks.

Design of tooling, including:		
- 3-D modelling of the workpiece	Cost:	1,6 MDKK
- Simulations	Cost:	20 man-weeks.
- Research an development expenditures	Cost:	1,5 MDKK
- Consultants	Cost:	1,0 MDKK
- Use of mock-ups	Cost:	50 man-weeks.
- Scale models and demonstrations	Cost:	48 man-weeks.
- Manufacturing processes	Cost:	3.0 MDKK
Generation of design specifications, including specifications for:		
- Operating and maintenance procedures	Cost:	40 man-weeks.
- Hardware and software	Cost:	1.0 MDKK
- Installation	Cost:	12 man-weeks.
- Testing	Cost:	12 man-weeks.
- Performance measurement	Cost:	10 man-weeks.

Procurement/adaptation of tooling for remote disassembly/segmentation of complex geometric subcomponents (highly automated articulated manipulators, handling equipment for remote segmentation).
As mentioned the planning and projecting under this point has not been performed at this early stage of decommissioning, whereby the procurement and adaption of the necessary tooling must be a qualified guess.

Cost: 15 MDKK

Procurement/adaptation of:
- Remote- viewing systems for underwater operations.
- Feedback and control systems for underwater operations.
- Turntables for underwater operations.
- Support systems for maintaining water clarity.
- Support systems for controlling or eliminating the formation of explosive mixtures of
- gases generated in the cutting or from the dissolution of water.

Cost: 10 MDKK

04.1102 Design and procurement of special tools for dismantling other components or structures.
- Design of special tooling, the adaptation and modification of existing tooling for dismantling when manual disassembly is not practical or when commercially available tooling is not suit-

able. -Leasing of special tooling, including concrete coring, sawing or other cutting device, demoli-tion hammers, etc., which, if purchased would be cost-prohibitive for smaller applica-tions.

Cost: 5 MDKK

04.1200 Dismantling operations on reactor vessel and internals.

Preparation of the work area for dismantling, extracting and packaging the waste for disposal

Cost: 80 man-weeks.

Installation of handling devices and protection systems.

Cost: 20 man-weeks.

Disconnecting of reactor vessel after retraction of horizontal liners.

Cost: 30 man-weeks.

Monitoring of the disassembly.
Cost: Included in Applied Health Physics, cf. ref. 1 section 6.9.

Operation of the segmentation tooling.

Cost: 40 man-weeks.

Maintenance and change-out of support equipment (purification and ventilation filters etc.).

Cost: 8 man-weeks.

Loading and processing containers for transport.

Cost: 20 man-weeks.

Removal of handling devices and protection systems.

Cost: 20 man-weeks.

04.1300 Removal of primary and auxiliary systems.

04.1301 Removal of primary and auxiliary systems in reactor facilities
De-energising, disconnecting, disassembly and segmentation of primary an auxiliary equip-ment 01- system inside D_2O-room (heat exchangers, vessels, pumps, pipes etc.)

Cost: 100 man-weeks.

Removal, rigging/transport of the material to a local or centralised waste packaging/prepara-tion area.
In this connection it has to be considered if the existing Hot Cells facility should be reopened or a new temporary hot cell facility should be erected in order to be able to handle radioactive components from the decommissioning of the other nuclear facilities.
Without reopening cost for Hot Cells Cost: 30 man-weeks.

04.1302 Dismantling and removal of contaminated equipment, piping, liners and internal sy-stems outside D_2O–room but inside containment.
De-energising, disconnecting, segmentation of primary and auxiliary systems outside D_2O-room but inside containment:

- 02 He-system	Cost:	60 man-weeks.
- 03 Graphite CO_2 systems	Cost:	30 man-weeks.
- 04 Secondary cooling system (inside containment)	Cost:	30 man-weeks.
- 05 Shield cooling system	Cost:	15 man-weeks.

- 09 Equipment for active handling incl. Internal Storage Block (incl. in 04.1000)
- 10 Control elements (Coarse Control Arms, Safety Rods, Fine Control Rod) Cost: 100 man-weeks.
- 11 Industrial instrumentation Cost: 40 man-weeks.
- 12 Nuclear instrumentation Cost: 60 man-weeks.
- 13 Interlock- and safety instrumentation Cost: 50 man-weeks.
- 14 Ventilation systems Cost: 200 man-weeks.

In - ref. 1 - the dismantling and removal of the ventilation system was listed to 46 MDKK, as this was the amount from the "PRICE" calculations made by UKAEA on the Dounreay Reactor in Scotland (Reactor type similar to DR3).
However the necessary resources for the job at DR3 has been judged to only 200 man-weeks, as the radioactive contamination level here is much lower than at the Dounreay reactor.

- 15 Electrical power supply Cost: 100 man-weeks.
- 16 Experimental tubes Cost: 30 man-weeks.
- 25 He-collection system Cost: 20 man-weeks.
- 29 Pressurised air system Cost: 70 man-weeks.
- 30 Common shared equipment for irradiation experiments Cost: 20 man-weeks.
- 42 -43-44 Isotope irradiation facilities, Si- irradiation facility, Mo- prod. facility Cost: 130 man-weeks.
- 68 Water filled neutron scattering plug Cost: 40 man-weeks.
- 81 High-temperature rig Cost: 10 man-weeks.
- 90 Common shared equipment for beam experiments Cost: 60 man-weeks.
- 161 Cold neutron source and neutron guide tube Cost: 60 man-weeks.

Cost: 15 men during 75 weeks = 1125 man-weeks.

04. 1400 Removal of biological shield, secondary structures and containment.

Dismantling of the activated portion of the biological shield, including removal of the top shield, graphite reflector, boron shield, water-cooled lead shield, and surrounding steel tank. This perhaps is the most intricate decommissioning job in the whole decommissioning programme, due to the fact that the steel tank constitutes a very intense and extended radiation source, which at the same time is moulded into the concrete of the biological shield with no provisions planned for dismantling.
It is considered necessary with implementation and extended use of remote operated heavy robots and other remote handling equipment to remove the reactor internals.

Cost: 80 MDKK

(Amount from “UKAEA preliminary price estimate for the decommissioning of the test reactor DMTR at the Dounreay Site).

Alternatively it should be evaluated if a removal and storing of the reactor block (about 800 tons) as a whole should be possible. Possibly the weight could be reduced by suitable “slicing” of the biological shield.
This solution is available only if Risø is selected as the place for final storage. It is expected, that this solution would be considerably cheaper than removing the reactor internals.

04.1500 Removal of other material/equipment from containment structure and all other facilities, or removal of entire contaminated facilities.

Removal of contaminated and activated materials (including structural), exceeding release levels from:

- Containment: Minor task
- Other systems:

The systems that are expected to contain considerable amounts of contamination are the active waste water systems and the systems in the active Handling Bay (AH-hall). The storage facilities in the AH-bay contain large amounts of reinforced concrete structures. The demolition of these structures has at present not been projected, whereby the amount of resources needed is not known with certainty.

Cost:	Active vent. System-14	5 men in 20 weeks =	100 man-weeks.
	Active waste water system-00	5 men in 40 weeks =	200 man-weeks.
	Active Handling Bay (storage facilities)	10 men in 60 weeks =	600 man-weeks.
Total	900 man-weeks.		

04.1600 Removal and disposal of asbestos.

Not considered as a specific problem (although some quantities of "Eternit"- building plates are present)

04.1700 Removal of pool linings.

No reactor pool is present. Removal of pool linings in the AH-bay pool is evaluated above.

04.1800 Building decontamination.

04.1801 Removal of contamination from areas and structures in all buildings and stacks.
It is not expected that contamination is present in structures and buildings. Surveys should be carried out inside the stack and around active wastewater tanks.

Cost: 10 man-weeks.

04.1802 Removal of embedded pipes in buildings.

Cost: 50 man-weeks.

04.1803 Removal of structures/facilities to gain access to radionuclides that may have breached design boundaries.

Cost: no significant.

04.1900 Environmental cleanup.

04.1901 Removal of embedded pipes outside building.

Cost: 20 man-weeks.

04.1902 Removal of structures/facilities to gain access to radionuclides that may have breached design boundaries.
Not expected

04.1903 Removal of contamination from areas and structures outside all buildings and stacks.
At present no contamination exists outside buildings and stacks.
During the decommissioning period some contamination may arise, caused by the many necessary transports of radioactive material. Some efforts may be necessary to remove this final contamination.

Cost: 10 men in 8 weeks = 80 man-weeks.

04.2000 Final radioactivity survey.

Described in ref. 1 under item 6.9 and Appendix 5.

04.2100 Characterisation of radioactive materials.

Described in ref. 1 Appendix 5.

04.2200 Decontamination for recycling and reuse.

Cost: 2 men during 40 weeks during 10 years = 800 man-weeks.

04.2300 Personnel training.

Cost: 50 men during 4 weeks during 20 years = 4000 man-weeks.

04.2400 Asset recovery: Sale/transfer of metal or materials, and salvaged equipment or components for recycling or reuse.

No asset recovery is calculated.

05 WASTE PROCESSING AND STORAGE. (Cost: 15 MDKK)

Cost for a final disposal facility is not included in this document.

Section 5 comprises a number of activities aiming at preparing the dismantled components either for final disposal as radioactive waste, or for release for restricted or unrestricted recycle or reuse.
The conditions for reuse and the activity limits for restricted and unrestricted recycle are not known at the moment. This of course gives uncertainty in the evaluation of the economic expenditures within this area of the decommissioning task

05.0100 Waste processing and storage safety analysis.
Excluding final disposal analysis Cost: 20 man-weeks

05.0400 Processing of system fluids from facility operations.
It is assumed that the waste can be treated by already existing treatment plants.

05.1200 Waste processing of decommissioning waste.
Waste treatment plant will deliver 500 concrete containers are judged to be able to contain the decommissioning waste.

Cost: 15 MDKK

06 SITE SECURITY, SURVEILLANCE AND MAINTENANCE.

As long as working operations with free radioactive material are carried out at the site it is considered necessary to maintain surveillance with guards and automatic monitoring systems.
Cost: Included in management cost. (See ref. 1.)

07 SITE RESTORATION, CLEANUP AND LANDSCAPING. (Cost: 21 MDKK)

In general, section 7 considers the non-radiological portions of plant decommissioning.
It is presumed that the ground has to be left over as “Green Field” without restrictions to use.

07.0100 Demolition or restoration of buildings.

07.0101 Dismantling of “balance-of-plant” systems and building components.

This comprises the turbine-generator group and condenser system, which is not relevant to DR3.

07.0102 Dismantling of the structure.
Primarily the reactor hall and adjacent auxiliary buildings.
Cost: 10 MDKK

(15 MDKK "UKAEA preliminary price estimate DMTR Dounreay,
but DR3 auxiliary systems are considered less radioactive contaminated).
07.0103 Dismantling of the stack. Cost: 0.3 MDKK

07.0200 Final cleanup and landscaping. Cost: 10 MDKK

07.0300 Independent compliance verification with cleanup and/or site-reuse standards
Cost: 1 MDKK

07.0400 Perpetuity funding/surveillance for limited or restricted release of property
Cost: Not considered.

08 PROJECT MANAGEMENT, ENGINEERING AND SITE SUPPORT

See ref. 1. Section 9.

09 RESEARCH AND DEVELOPMENT

See ref. 1. Section 6.9.3.

10 FUEL AND NUCLEAR MATERIAL

This section covers costs relating to evacuation of the spent fuel elements and/or nuclear material.
Activities relating to this section are already going on under current budget (abt 50 MDKK). Therefore no future expenditures are budgeted.

4 Conclusions

In the report “Decommissioning of the Nuclear Facilities at Risø National Laboratory” (Risø-R-1250(EN)) the total costs of decommissioning activities related to Reactor DR 3 were estimated to about 437 MDKK.
In this report the revised cost are evaluated to 301 MDKK.
The difference in evaluated costs mainly originals from Section 04 “Dismantling Activities” which by a closer evaluation are reduced from about 293 MDKK to about 249 MDKK.
Further the costs from section 10 “Fuel and Nuclear Material” 68 MDKK are omitted from the costs, as activities under this item are already paid under the current budget (year 2001).
Programme Manager Mr. Roy Manning from UKAEA (United Kingdom Atomic Energy Authorities) reviewed this report and gave many valuable comments (See app. 1.)
The original cost estimates from the review group have been maintained except for minor corrections.
In the conclusive comment from Mr. Roy Manning it is stated as follows:

“At the level of detail that has been applied to the development of the estimate and considering the comparison with UKAEA's material test reactors it is reasonable to consider that the latest Risø estimate for DR3 represents a value that will be more than adequate to fund all activities to remove the liability and to restore the site to 'green field' status. There is a high probability, perhaps more than 90% that the total value of the project will fall below the estimate value.”

5 Acknowledgements

The editor wishes to thank his good colleague Kurt Lauridsen for his valuable comments to the revision. Also the information provided by other colleagues at Risø is gratefully acknowledged.

Cost estimate - DR 3						Date/Time:	2001-11-12	
Labour cost per hour (Danish krones = kr.)		350				Labour costs	Sub. Section	Section
Labour cost per week (Danish krones = kr.)		12.950				+Procurement	costs	costs
	Crew	**Weeks**	**Man-weeks**	**Labour costs**	**Procurement**	**Sum 3**	**Sum 2**	**Sum 1**
01 PRE-DECOMMISSIONING ACTIONS	0		0	0		0		0
01.0100 Decommissioning planning	0		0	0		0	0	
01.0101 Strategic studies	0		0	0		0		
01.0102 Conceptual planning	0		0	0		0		
01.0103 Detailed planning	0		0	0		0		
01.0104 Safety and environmental studies	0		0	0		0		
01.0200 Authorisation	0		0	0		0	0	
01.0201 License applications and license approvals	0		0	0		0		
01.0202 Public consultation and public inquiry	0		0	0		0		
01.0300 Radiological surveys for planning and licensing	0		0	0		0	0	
01.0400 Hazardous-material surveys and analysis	0		0	0		0	0	
01.0500 Prime contracting selection	0		0	0		0	0	
02 FACILITY SHUTDOWN ACTIVITIES	0		0	0		0		7.433.300
02.0100 Plant shutdown and inspection	0		0	0		0	4.014.500	
02.0101 Termination of operation, plant stabilisation, isolation and inspection	3	100	300	3.885.000		3.885.000		
02.0102 Facility reuse	1	10	10	129.500		129.500		
02.0200 Removal of fuel and/or nuclear-fuel materials	0		0	0		0	906.500	
02.0201 Defuelling and transfer of fuel to temporary spent-fuel storage	7	10	70	906.500		906.500		
02.0202 Nuclear-fuel material inventory recovery				0		0		
02.0300 Drainage and drying or blowdown of all systems not in operation	4	4	16	207.200		207.200	207.200	
02.0400 Sampling for radiological inventory characterisation after plant shutdown, defuelling and drainage and drying or blowdown of systems	0		0	0		0	0	
02.0401 Sampling for radiological inventory characterisation in the installations after plant shutdown, defuelling and drainage and drying or blowdown of systems	0		0	0		0		
02.0402 Subgrade soil sampling and monitoring wells to map contamination plumes	0		0	0		0		
02.0500 Removal of system fluids (water, oils, etc.)	1	1	1	12.950		12.950	12.950	
02.0600 Removal of special system fluids (D_2O, sodium, etc.)	2	25	50	647.500		647.500	647.500	
02.0700 Decontamination of systems for dose reduction	3	4	12	155.400		155.400	155.400	
02.0800 Removal of waste from decontamination	0		0	0		0	0	
02.0900 Removal of combustible material	5	22	110	1.424.500		1.424.500	1.424.500	

02.1000 Removal of spent resins	0		0	0		0	0	
02.1100 Removal of other waste from facility operations	1	5	5	64.750		64.750	64.750	
02.1200 Isolation of power equipment	0		0	0		0	0	
02.1300 Asset recovery: Resale/transfer of facility equipment and components as well as surplus inventory to other licensed (contaminated) and unlicensed (non-contaminated) facilities	0		0	0		0	0	
03 PROCUREMENT OF GENERAL EQUIPMENT AND MATERIAL	0		0	0		0		9.000.000
03.0100 General site dismantling equipment	0		0	0	8.000.000	8.000.000	8.000.000	
03.0200 General equipment for personnel/tooling decontamination	0		0	0	1.000.000	1.000.000	1.000.000	
03.0300 General radiation protection and health physics equipment	0		0	0		0	0	
03.0400 General security and maintenance equipment for long-term storage	0		0	0		0	0	
04 DISMANTLING ACTIVITIES	0		0	0		0		248.358.250
04.0100 Decontamination of areas and equipment in buildings to facilitate dismantling	0		0	0		0	0	
04.0200 Drainage of spent-fuel pool and decontamination of linings	3	10	30	388.500		388.500	388.500	
04.0300 Preparation for dormancy	0		0	0		0	12.500.000	
04.0301 Zoning for long-term storage	0		0	0	4.500.000	4.500.000		
04.0302 Removal/disposition of inventory not suitable for long-term	0		0	0	8.000.000	8.000.000		
04.0400 Dismantling and transfer of contaminated equipment and material to containment structure for long-term storage	0		0	0		0	0	
04.0500 Sampling for radiological inventory characterisation in the installations after zoning and in view of dormancy	0		0	0		0	0	
04.0600 Site reconfiguration, isolating and securing structures	0		0	0		0	0	
04.0601 Reconfiguration and maintenance of essential services and facilities to support long-term storage and/or decommissioning	0		0	0		0		
04.0602 Site boundary reconfiguration	0		0	0		0		
04.0603 Construction of temporary enclosures, storing, structural enhancements, etc. to support site remediation	0		0	0		0		
04.0604 Stabilisation of radioactive and hazardous waste pending	0		0	0		0		
04.0700 Facility (controlled area) hardening, isolation or entombment	0		0	0		0	0	
04.0800 Radiological inventory characterisation for decommissioning and decontamination	0		0	0		0	0	
04.0900 Preparation of temporary waste storage area	0		0	0	15.000.000	15.000.000	15.000.000	
04.1000 Removal of fuel-handling equipment	5	20	100	1.295.000		1.295.000	1.295.000	

04.1100 Design, procurement, and testing of special tooling/equipment for remote dismantling	0		0	0		0	44.212.400	
04.1101 Design and procurement of special tools for dismantling the reactor vessel and internals	8	59	472	6.112.400	33.100.000	39.212.400		
04.1102 Design and procurement of special tools for dismantling other components or structures	0		0	0	5.000.000	5.000.000		
04.1200 Dismantling operations on reactor vessel and internals	2	109	218	2.823.100		2.823.100	2.823.100	
04.1300 Removal of primary and auxiliary systems	0		0	0		0	16.252.250	
04.1301 Removal of primary and auxiliary systems in reactor facilities	5	26	130	1.683.500		1.683.500		
04.1302 Dismantling and removal of contaminated equipment, piping, liners and internal systems in non-reactor nuclear facilities	15	75	1.125	14.568.750		14.568.750		
04.1400 Removal of biological/thermal shield	0		0	0	80.000.000	80.000.000	80.000.000	
04.1500 Removal of other material/equipment from containment structure and all other facilities, or removal of entire contaminated facilities	10	90	900	11.655.000		11.655.000	11.655.000	
04.1600 Removal and disposal of asbestos	0		0	0		0	0	
04.1700 Removal of pool linings	0		0	0		0	0	
04.1800 Building decontamination	0		0	0		0	777.000	
04.1801 Removal of contamination from areas and structures in all buildings and stacks	2	5	10	129.500		129.500		
04.1802 Removal of embedded pipes in buildings	5	10	50	647.500		647.500		
04.1803 Removal of structures/facilities to gain access to radionuclides that may have breached design boundaries	0		0	0		0		
04.1900 Environmental cleanup	0		0	0		0	1.295.000	
04.1901 Removal of embedded pipes outside buildings	2	10	20	259.000		259.000		
04.1902 Removal of structures/facilities to gain access to radionuclides that may have breached design boundaries	0		0	0		0		
04.1903 Removal of contamination from areas and structures outside all buildings and stacks	10	8	80	1.036.000		1.036.000		
04.2000 Final radioactivity survey	0		0	0		0		
04.2100 Characterisation of radioactive materials	0		0	0		0		
04.2101 Characterisation of radioactive materials for recycling and reuse	0		0	0		0		
04.2102 Characterisation of radioactive materials for final disposal	0		0	0		0		
04.2200 Decontamination for recycling and reuse	2	400	800	10.360.000		10.360.000	10.360.000	
04.2300 Personnel training	50	80	4.000	51.800.000		51.800.000	51.800.000	
04.2400 Asset recovery: Sale/transfer of metal or materials, and salvaged equipment or components for recycling or reuse	0		0	0		0	0	
05 WASTE PROCESSING, STORAGE AND DISPOSAL	0		0	0		0		15.259.000

05.0100 Waste processing, storage and disposal safety analysis	4	5	20	259.000		259.000	259.000	
05.0200 Waste-transport feasibility studies	0	0	0	0		0	0	
05.0300 Special permits, packaging and transport requirements	0		0	0		0	0	
05.0400 Processing of system fluids (water, oils, etc.) from facility operations	0		0	0		0	0	
05.0401 Processing	0		0	0		0		
05.0402 Packaging	0		0	0		0		
05.0403 Transport	0		0	0		0		
05.0500 Processing of special system fluids (D2O, sodium, etc.) from facility operations	0		0	0		0	0	
05.0501 Processing	0		0	0		0		
05.0502 Packaging	0		0	0		0		
05.0503 Transport	0		0	0		0		
05.0600 Processing of waste from decontamination during facility operations	0		0	0		0	0	
05.0601 Processing	0		0	0		0		
05.0602 Packaging	0		0	0		0		
05.0603 Transport	0		0	0		0		
05.0700 Processing of combustible material from facility operations	0		0	0		0	0	
05.0701 Processing	0		0	0		0		
05.0702 Packaging	0		0	0		0		
05.0703 Transport	0		0	0		0		
05.0800 Processing of spent resins from facility operations	0		0	0		0	0	
05.0801 Processing	0		0	0		0		
05.0802 Packaging	0		0	0		0		
05.0803 Transport	0		0	0		0		
05.0900 Processing of other nuclear and hazardous materials from facility operations	0		0	0		0	0	
05.0901 Processing	0		0	0		0		
05.0902 Packaging	0		0	0		0		
05.0903 Transport	0		0	0		0		
05.1000 Storage of waste from facility operations	0		0	0		0	0	
05.1001 Preparation of storage facility	0		0	0		0		
05.1002 Waste storage	0		0	0		0		
05.1003 Storage of radioactive waste from facility operations	0		0	0		0		
05.1004 Decontamination of storage facility	0		0	0		0		
05.1005 Dismantling/disposal of storage facility	0		0	0		0		

05.1100 Disposal of waste from facility operations	0		0	0		0	0	
05.1101 Preparation of disposal site	0		0	0		0		
05.1102 Waste disposal	0		0	0		0		
05.1103 Disposal of radioactive waste from facility operations	0		0	0		0		
05.1104 Disposal of non-radioactive waste from facility operations	0		0	0		0		
05.1200 Processing of decommissioning waste	0		0	0		0	15.000.000	
05.1201 Processing of radioactive decommissioning waste	0		0	0		0		
05.1202 Processing of non-radioactive decommissioning waste	0		0	0		0		
05.1203 Waste containers	0		0	0	15.000.000	15.000.000		
05.1300 Packaging of decommissioning waste	0		0	0		0	0	
05.1301 Packaging of radioactive decommissioning waste	0		0	0		0		
05.1302 Packaging of non-radioactive decommissioning waste	0		0	0		0		
05.1400 Transport of decommissioning waste	0		0	0		0	0	
05.1401 Transport of radioactive decommissioning waste	0		0	0		0		
05.1402 Transport of non-radioactive decommissioning waste	0		0	0		0		
05.1500 Storage of decommissioning waste	0		0	0		0	0	
05.1501 Preparation of storage facility	0		0	0		0		
05.1502 Waste storage	0		0	0		0		
05.1503 Storage of radioactive decommissioning waste.	0		0	0		0		
05.1504 Decontamination of storage facility	0		0	0		0		
05.1505 Dismantling/disposal of storage facility	0		0	0		0		
05.1600 Disposal of decommissioning waste	0		0	0		0	0	
05.1601 Preparation of disposal site	0		0	0		0		
05.1602 Decommissioning waste disposal	0		0	0		0		
05.1603 Disposal of radioactive decommissioning waste on disposal site	0		0	0		0		
05.1604 Disposal of non-radioactive decommissioning waste	0		0	0		0		
06 SITE SECURITY, SURVEILLANCE AND MAINTENANCE	0		0	0		0		0
06.0100 Site security operation and surveillance	0		0	0		0	0	
06.0200 Inspection and maintenance of buildings and systems in operation	0		0	0		0	0	
06.0300 Site upkeep	0		0	0		0	0	
06.0400 Energy and water	0		0	0		0	0	
06.0500 Periodic radiation and environmental survey	0		0	0		0	0	
07 SITE RESTORATION, CLEANUP AND LANDSCAPING	0		0	0		0		21.300.000
07.0100 Demolition or restoration of buildings	0		0	0		0	10.300.000	
07.0101 Dismantling of "balance-of-plant" systems and building	0		0	0		0		
07.0102 Dismantling of the structure	0		0	0	10.000.000	10.000.000		
07.0103 Dismantling of the stack	0		0	0	300.000	300.000		
07.0200 Final cleanup and landscaping	0		0	0	10.000.000	10.000.000	10.000.000	

07.0300 Independent compliance verification with cleanup and/or site-reuse standards	0		0	0	1.000.000	1.000.000	1.000.000	
07.0400 Perpetuity funding/surveillance for limited or restricted release of property	0		0	0		0	0	
08 PROJECT MANAGEMENT, ENGINEERING AND SITE SUPPORT	0		0	0		0		0
08.0100 Mobilisation and preparatory work	0		0	0		0	0	
08.0101 Mobilisation of construction equipment and facilities	0		0	0		0		
08.0102 Mobilisation of personnel	0		0	0		0		
08.0103 Set-up/construction of temporary facilities	0		0	0		0		
08.0104 Construction of temporary utilities	0		0	0		0		
08.0105 Temporary relocations	0		0	0		0		
08.0200 Project management and engineering services	0		0	0		0	0	
08.0201 Project manager and his staff	0		0	0		0		
08.0202 Planning and cost control	0		0	0		0		
08.0203 Quality assurance and quality surveillance	0		0	0		0		
08.0204 Procurement, warehousing, and materials handling	0		0	0		0		
08.0205 General/subcontractor administration	0		0	0		0		
08.0206 Documentation and records control	0		0	0		0		
08.0207 Engineering support	0		0	0		0		
08.0300 Public relations	0		0	0		0	0	
08.0400 Support services	0		0	0		0	0	
08.0401 Housing, office equipment, site services	0		0	0		0		
08.0402 Computer support	0		0	0		0		
08.0403 Decommissioning support including chemistry, decontamination and field supervision	0		0	0		0		
08.0404 Waste-management support	0		0	0		0		
08.0500 Health and safety	0		0	0		0	0	
08.0501 Health physics	0		0	0		0		
08.0502 Radiation protection and monitoring	0		0	0		0		
08.0503 Industrial safety	0		0	0		0		
08.0600 Demobilisation	0		0	0		0	0	
08.0601 Removal of temporary facilities	0		0	0		0		
08.0602 Removal of temporary utilities	0		0	0		0		
08.0603 Demobilisation of construction equipment and facilities	0		0	0		0		
08.0604 Demobilisation of personnel	0		0	0		0		
09 RESEARCH AND DEVELOPMENT	0		0	0		0		0
09.0100 Research and development of decontamination, radiation measurement and dismantling processes, tools and equipment	0		0	0		0	0	

09.0200 Simulation of complicated work on model	0		0	0		0	0	
10 FUEL AND NUCLEAR MATERIAL				0		0		0
10.0100 Transfer of fuel or nuclear material from facility or from temporary storage to intermediate storage				0		0	0	
10.0200 Intermediate storage	0		0	0		0	0	
10.0201 Wet intermediate storage	0		0	0		0		
10.0202 Dry intermediate storage and containers	0		0	0		0		
10.0300 Dismantling/disposal of temporary storage facility	0		0	0		0	0	
10.0301 Decontamination of temporary storage facility	0		0	0		0		
10.0302 Dismantling/disposal of temporary storage facility	0		0	0		0		
10.0400 Preparation of transfer of fuel or nuclear material from intermediate storage to final disposition	0		0	0		0	0	
10.0500 Dismantling/disposal of intermediate storage facility	0		0	0		0	0	
10.0501 Decontamination of intermediate storage facility	0		0	0		0		
10.0502 Dismantling/disposal of intermediate storage facility	0		0	0		0		
11 OTHER COSTS	0		0	0		0		0
11.0100 Owner costs	0		0	0		0	0	
11.0101 Implementation of transition plan	0		0	0		0		
11.0102 Capital expenditures	0		0	0		0		
11.0200 General, overall (not specific) consulting costs	0		0	0		0	0	
11.0300 General, overall (not specific) regulatory fees, inspections, certifications, reviews, etc.	0		0	0		0	0	
11.0400 Taxes	0		0	0		0	0	
11.0500 Insurances	0		0	0		0	0	
11.0600 Overheads and general administration	0		0	0		0	0	
11.0700 Contingency	0		0	0		0	0	
11.0701 Risk, financial assurance versus inherent uncertainties	0		0	0		0		
11.0702 Escalation of high-risk cost elements	0		0	0		0		
11.0800 Interest on borrowed money	0		0	0		0	0	
11.0900 Asset recovery: Resale/transfer of general equipment and material	0		0	0		0	0	
Investments at Waste Plant						0	0	0
			8.529	110.450.550	190.900.000	301.350.550	301.350.550	301.350.550

6 References

1. Decommissioning of the Nuclear Facilities at Risø National Laboratory
   Edited by Kurt Lauridsen Risø-R-1250(EN)

Appendix 1

UKAEA

Planning, Performance & Engineering Division

Klaus Iversen
Ris0 National Laboratory
Roskilde

26 October 2001 Reference 18691709/RM/01

Direct line
0044 1235 43 6956
Direct facsimile
0044 1235 43 6930

Dear Klaus

REVISED COST ESTIMATE FOR THE DECOMMISSIONING OF REACTOR DR3

Thank you for your note dated 11 October 2001 and the attached 'revised' cost estimate for DR3.

Further to your instructions I have reviewed the estimate and offer the following comments. I would point out that I have not considered how the current estimate has changed from its original issue in Kurt Lauridsen's report (Ris0-R-1250(EN).

1. In considering the estimate I have drawn on information from UKAEA's experience on the part decommissioning of similar reactors in the UK namely DIDO and PLUTO at Harwell and DMTR at Dounreay. In particular I have discussed the estimate with Mr John Buffery who has been responsible, on the Harwell site, for the decommissioning of the DIDO and PLUTO reactors.

2. Firstly some comments about the overall construction of the estimate:

   2.1. 90% of the overall value of the estimate is represented by 15 items or 36% of the costed items.

   These are:

	Value (million kr)	Contribution to total Estimate Value
04.1400 Removal of biological/thermal shield	80.0	25,7%
10.0100 Transfer of fuel or nuclear material from facility or from temporary storage to intermediate storage	45.5	14.6%
04.1101 Design and procurement of special tools for dismantling the reactor vessel and internals	37.1	11.9%
Investments at Waste Plant	25.0	8.0%
04.2300 Personnel training	17.1	5.5%
05.1203 Waste containers	15.0	4.8%
07.0102 Dismantling of the structure	10.0	3.2%
04.1302 Dismantling and removal of contaminated equipment, piping, liners and internal systems in non-reactor nuclear facilities	9.6	3.1%
03.0100 General site dismantling equipment	8.0	2.6%
04.1500 Removal of other material/equipment from containment structure and all other facilities, or removal of entire contaminated facilities	7.7	2.5%

04.2200 Decontamination for recycling and reuse	6.8	2.2%
04.0302 Removal/disposition of inventory not suitable for long term storage	6.0	1.9%
04.0601 Reconfiguration and maintenance of essential services and facilities to support long-term storage and/or decommissioning operations	5.0	1.6%
04.0603 Construction of temporary enclosures, storing, structural enhancements, etc. to support site remediation	5.0	1.6%
04.1102 Design and procurement of special tools for dismantling other components or structures	5.0	1.6%

2.2. More than 50% of the overall value of the estimate is represented by only three items and one of these items is the transfer of fuel and other nuclear materials. This item was dealt with as part of the 'operational' activities for UKAEA's material test reactors and as such is not considered as a decommissioning cost. The final treatment and disposal of fuel, via reprocessing or as waste, is a very complicated issue with considerable uncertainties. As such it is difficult to judge whether this provision is adequate. It might be more appropriate to take this item from the decommissioning estimate and account for it separately.

2.3. Many of the line items in the 'standard cost item' list are not utilized. This is distracting and unhelpful. These should be removed.

2.4. The estimate can be summarized as follows:

	Million kr	
02-Facility Shutdown Activities	5.34	2%
03-Procurement of General Equipment and Materials	9.00	3%
04-Dismantling Activities	195.38	63%
05-Waste Processing Storage & Disposal	15.17	5%
07-Site Restoration, Cleanup and Landscaping	16.30	5%
10-Fuel and Nuclear Materials	45.50	15%
Investments in Waste Plants	25.00	8%
	311.70	

2.5. The provisions for 'Facility Shutdown Activities' and 'Procurement of Equipment' are considered to be adequate.

2.6. The item 'Dismantling activities' is made up of two principle elements. Forty percent (80 mkr) is set against a single task 'Removal of biological/thermal shield' and is derived from a preliminary PRICE estimate for DMTR at Dounreay. Sixty percent (115 mkr) comprises 21 line items, the costs of which have been derived from man-hour estimates. The latter equates to a 30 strong team working on these activities for approximately 6 years. Based on UKAEA's experience on DIDO and PLUTO, this is judged to be higher than necessary.

2.7. The costs associated with final waste disposal is not included so to avoid confusion the title of this summary item should be changed, omitting reference to disposal. The cost of waste containers, which dominates this item, is considered to be adequate.

2.8. The estimate for 'Site Restoration', which includes the dismantling of the balance of plant, demolition of the structure, final cleanup and landscaping is considered to be low. Consider that this task is likely to last at least one year with a complement of approx. 30 staff. This would yield a cost of about 25 mkr including specialist demolition plant.

2.9. There is no description of the item 'Investments at Waste Plant'. Assume this relates to the provision of intermediate storage for radwaste (ILW and LLW). If so this might be too light. A figure of at least double this figure might be more appropriate. This item should be included under either item 03 or 05.

3. The estimate has been compared to UKAEA's Level 2 Study estimates for the decommissioning of DMTR.

   3.1. The overall duration and cost (excluding waste costs and inflated to. 2001 prices) estimated for DMTR for all decommissioning activities prior to the decommissioning of the reactor proper i.e. Risø estimate items 02, 03, and 04 (excluding item 04.1400) was 4 years and 30 mkr. This compares to 6 years and 129 mkr suggested by the Risø estimate.

   3.2. The overall cost (excluding waste costs and inflated to 2001 prices) estimated for DMTR for the decommissioning of the reactor proper and site clearance work i.e. Risø estimate items 04.1400, 07 and 'Investments in Waste Plants' is 136 mkr. This compares to 121 mkr suggested by the Risø estimate. Note that DMTR is assumed to be decommissioned to 'brown field' status.

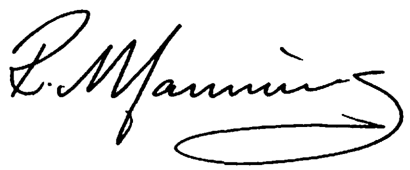
   3.3. In overall terms (excluding items 05, and 10) the Risø cost estimate is 85 mkr (50%) higher than the equivalent DMTR estimate.

   3.4. The cost of disposal for DMTR ILW and LLW is estimated to cost approximately 40 mkr.

4. Actual experience on decommissioning work on DIDO and PLUTO has suggested that work involved in (3.1) (less infrastructure and C&M costs) has been of the order of 80 mkr per reactor. Note this is higher than the DMTR estimate.

5. At the level of detail that has been applied to the development of the estimate and considering the comparison with UKAEA's material test reactors it is reasonable to consider that the latest Risø estimate for DR3 represents a value that will be more than adequate to fund all activities to remove the liability and to restore the site to 'green field' status. There is a high probability, perhaps more than 90% that the total value of the project will fall below the estimate value.

Yours sincerely



Roy Manning Section Manager -
Project Support

Copies: File

Bibliographic Data Sheet			**Risø-R-1291(EN)**

Title and authors

Revised Cost Estimate for the Decommissioning of the Reactor DR 3

Klaus Iversen

ISBN	ISSN
87-550-2935-3; 87-550-2936-1(Internet)	0106-2840
Department or group	Date
Risø Decommissioning	November 2001
Groups own reg. number(s)	Project/contract No(s)
Sponsorship	

Pages	Tables	Illustrations	References
39	1	4	1

Abstract (max. 2000 characters)

The report describes a revision of the cost estimate for the decommissioning of the research Reactor DR 3 as described in the report Risø-R-1250(EN) “Decommissioning of the Nuclear Facilities at Risø National Laboratory” Edited by Kurt Lauridsen.
The revision has been performed by the planning group in the Risø Decommissioning Department, and has been carried out as a discussion and evaluation of procedures methods and necessary resources to overcome the different phases of the the decommissioning task of the Reactor.

Descriptors INIS/EDB

Available on request from Information Service Department, Risø National Laboratory,
(Afdelingen for Informationsservice, Forskningscenter Risø), P.O.Box 49, DK-4000 Roskilde, Denmark.
Telephone +45 4677 4004, Telefax +45 4677 4013